IMPROVEMENT OF GAIN WITH FIBER LENGTH AND FIGURE OF MERIT IN DISCRETE RAMAN AMPLIFIER

Er. Jyoti Dhir[*]

Er. Vivek Gupta[**]

Abstract:

Fiber Raman amplifiers are important component of wavelength division multiplexed fiber optic communication systems. The number of pumps, fiber attenuation, on-off Raman gain and pumping schemes are main design criteria to operate these amplifiers. This paper investigates the counter propagating pumping in fiber Raman amplifier. In this paper three pumping powers are used and according to that the Raman gain is analysed when taken as a function of fiber length and figure of merit (FOM).

Keywords: Counter Pumping, Fiber Raman Amplifier, Discrete/Lumped Raman Amplifier, Figure of Merit and Fiber Length.

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[*] Student, Dept. of ECE, Rayat and Bahra Institute of Engg. & Biotechnology, Sahauran, Punjab

[**] Asstt. Professor, Dept. of ECE, Rayat and Bahra Institute of Engg. & Biotechnology, Sahauran,

I. INTRODUCTION

In the early 1970s, Stolen and Ippen [1] demonstrated Raman amplification in optical fibers. However, throughout the 1970s and the first half of the 1980s, Raman amplifiers remained primarily laboratory curiosities. In the mid 1980s many research papers elucidated the promise of Raman amplifiers, but much of that work was overtaken by EDFAs by the late 1980s [2]. However, in the mid to late 1990s, there was a resurged interest in Raman amplification. By the early part of 2000s, almost every long haul or ultra-long haul fiber optic transmission system uses Raman amplification. Modern lightwave communication systems have used full gain bandwidth of EDFAs, and increasing capacity has resulted into the need of broader bandwidth optical amplifiers in the systems [3]. Fiber Raman amplifiers are used nowadays as all Raman or long haul wavelength division multiplexing optical communication systems [4]. The design process of fiber Raman amplifiers involves the criteria of number of pumps, pumping schemes, selection of their powers, frequencies and cost and complexity etc.

The novelty of the work is that it achieved a better gain of the amplifier for a appropriate signal power. To analyze the model, three different signal powers are used to get the better result from all. In this paper the Raman gain is taken as a function of fiber length and figure of merit. Till now the Raman gain is observed as 35 dB [5]. Now from the model in this paper the Raman gain is observed as the better performance.

The paper in the section 1, presents introduction of Raman fiber amplifiers, section 2 discusses discrete Raman configuration. The section 3 describes the theoretical model prevalent in the area. In section 4 the results are discussed and while in section 5, conclusions of the work done has been drawn.

II. DISCRETE RAMAN CONFIGURATION

In LRA highly nonlinear fiber with a small core is utilized to increase the interaction between signal and pump wavelengths and thereby reduce the length of fiber required. Because of small scattering cross section Raman amplification may better fit in a DRA rather than a discrete one. Therefore, in designing LRAs, several challenges such as increasing efficiency and solving fundamental trade offs are required. The important parameters representing LRAs are: the wavelength and input power level of signal, the wavelength and input power level of pump and the type and length of the gain fiber. The length of the fiber in LRA is between 5 km to 40 km. the following properties in signal and pump wavelengths bands are required to design the amplifier in detail: the attenuation coefficient, the Raman gain coefficient for the given pump wavelengths, the Rayleigh backscattering coefficient and the nonlinear coefficient.

The targeted optical characteristics of a LRA usually gain, noise figure, output signal power level, optical signal to noise ratio, double Rayleigh backscattering noise power, nonlinear phase shift, and pump to signal power conversion efficiency. In this thesis report the work is done on the gain of the Raman amplifier. However, discrete Raman amplifiers have many attractive aspects over rare-earth-doped fiber amplifiers such as an erbium-doped fiber amplifier (EDFA) including arbitrary gain band, better adjustability of gain shape, and better linearity. The principal advantage of Raman amplification is its ability to provide distributed amplification within the transmission fiber, thereby increasing the length of spans between amplifier and regeneration sites.

Fig.1 shows the basic configuration of discrete Raman amplifier. It generally comprises a gain fiber, a directional coupler for combining the pump and the signal wavelength, and isolators at the input and output ends.

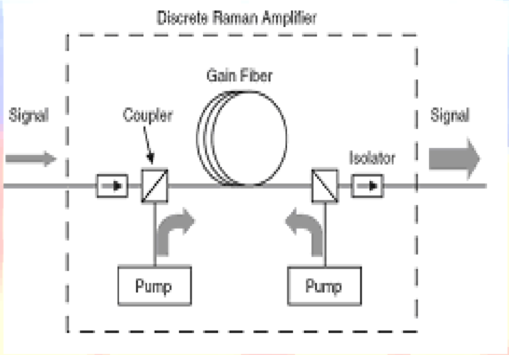

Fig 1: Discrete Raman amplifier in counter propagation configuration

The orientation of the pump can be either forward or backward with respect to the signal propagation, whereas the counter propagating one is called counter pumping; the copropagating pumping scheme is called copumping. There is also an option of bidirectional pumping, in which the gain fiber is pumped in both directions [6].

III. THEORATICAL MODEL

Under such conditions the saturated gain of the amplifier is given by:

$$G_s = \frac{G_A}{1+r_0G_A}$$

where r_0 is related to the signal to pump power ratio at the fiber input as and G_A is unsaturated gain or we can say that G_A is the total amplifier gain or on-off Raman gain.

If we use the typical values [6] as g_R= 3W^{-1}/km for a DCF, L_{eff}=1km, P_0~1.5W then the signal can be amplified by 20 db. Once the gain fiber and pump power are given, the net gain G(z) can be written explicitly as a function of the fiber length z.

$$G(z)=\exp(g_RP_0L_{eff}-a_sz) \qquad (1)$$

The first term indicates the on off Raman gain and other is the fiber attenuation. After taking the derivative of (1) with respect to z, seeking the condition for z in which the derivative becomes zero. The net gain is maximal when

$$z = -\frac{1}{\alpha_p}\ln\left(\frac{\alpha_s}{g_R P_0}\right)$$

where P_0 is the input pump power at z=0, ap is the attenuation constant for pump and g_R is Raman gain coefficient.

Now, the final proposed model is as follows:

$$\text{Gain} = -\ \frac{w_sP_p(0)G_s/w_sP_p(0)-w_pP_s(0)G_s}{\exp[-a_s/a_p(\ln(a_s/g_rP_0))]}$$

From my work, we can see the improved gain of Raman amplifier. According to the equations given above we can obtain better results of gain.

where w_s = angular frequency of signal

P_p = pump power

w_p = angular frequency of pump

P_s = signal power

Equations are taken from [7].

Also we can conclude the figure of merit as the ratio of Raman gain coefficient to the pump attenuation constant. By knowing figure of merit, the efficiency of the fiber for LRAs can be estimated and compared. Mathematically,

$$FOM= g_r/\alpha_p$$

IV. RESULTS AND DISCUSSION

For broadband amplification, one pumping power is not enough; big gain ripples makes it impossible to achieve large Raman gain. By appropriately choosing the multiple values a wide gain is obtained. In this paper, we will investigate LRAs with three values of signal power. So Raman gain is analysed in terms of fiber length and in FOM respectively.

Table 1:

Common set ups of simulation cases

Optical frequency of pump	980 nm
Optical frequency of signal	1350 nm
Saturated gain	19 dB
Pump power	200 mW
Signal attenuation constant	0.4 dB/km
Pump attenuation constant	0.65 dB/km
Raman gain coefficient	0.45 dB

Case 1: Raman gain with fiber length

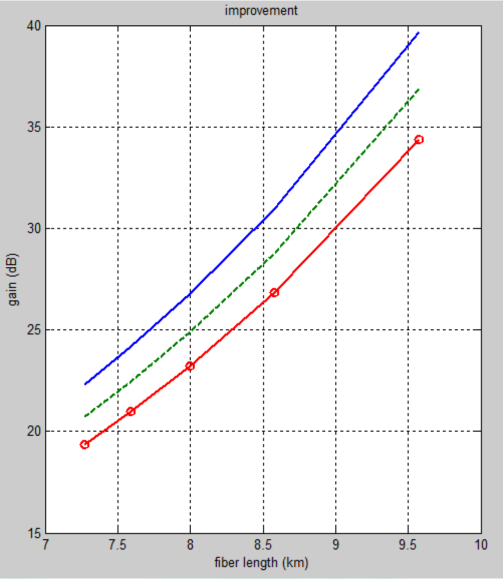

Fig 2: Raman gain with fiber length

In fig 2, it is quite clear that Raman gain is better than [5] at the length of 9.6 km. Three signal powers used are 155, 165, 175 and the respective Raman gain obtained is 39.6, 37.5, 34.5. So as we start increasing the power the value of Raman gain start decreasing. But, we have one advantage that at the same length we get the better Raman gain.

In case of fiber length , it takes some distance for the orthogonally polarized signal to adjust its state of polarization through polarization mode dispersion before it can experience the full Raman gain. Within the polarization mode dispersion diffusion length, fiber loss dominates and the signal power decreases beyond the diffusion length, Raman gain dominates and the signal power increases.

Case 2: Raman gain with FOM

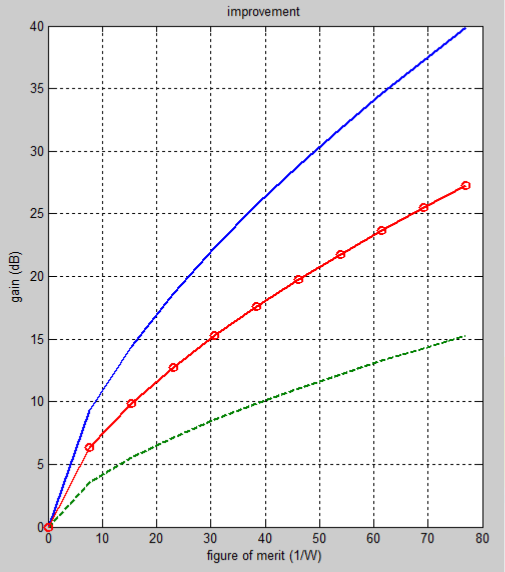

Fig 3: Raman gain with figure of merit

In fig 3, three signal powers used are 33, 35, 40 and the respective Raman gain achieved is 39.9, 27.5, 15.2. So as we start increasing the power the value of Raman gain start decreasing. FOM is totally dependent on Raman gain coefficient and pump attenuation coefficient so with change of one parameter figure of merit changes. Highest the value of FOM efficiency of the system increases. At the same FOM i.e. at 75 (1/W) we get highest Raman gain as 39.9 dB. Attenuation constant for signal is varied if signal power is varied. And Raman gain gain is dependent on attenuation constant.

V. CONCLUSION AND FUTURE SCOPE

With the use of lumped Raman amplifier in the counter propagation configuration we are successful to achieve a better gain performance which can increase the efficiency of system and the overall performance of the system is improved. With the increase or decrease of such values in our model we can further increase the value of Raman gain. As in this paper our motive is to increase the Raman gain, so it is accomplished with a factor of 4.9 dB when taken FOM as a variation with Raman gain and signal power is varied only and all other parameters are remain same as in case 1.

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